PATENT SPECIFICATION

DRAWINGS ATTACHED

1,131,624

1,131,624

Date of Application and filing Complete Specification: 9 Feb., 1966.
No. 5633/66.
Application made in Germany (No. Sch36656 VIa/31c) on 9 March, 1965.
Complete Specification Published: 23 Oct., 1968.

Index at acceptance —B3 F(1G, 11P, 13A3, 13A6)

Int. Cl.:—B 22 d 35/00

COMPLETE SPECIFICATION

Improvements in the Pouring of Molten Metals or Alloys into Moulds, such as Chill-Moulds for Continuous Casting

We, SCHLOEMANN AKTIENGESELLSCHAFT, of Steinstrasse 13, Düsseldorf, Germany, A German Body Corporate, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

For the pouring of melts, such as molten metals for example, into casting moulds, particularly chill-moulds, for continuous casting it is necessary to heat the melts to a temperature above their melting points, in order that they may have a sufficient degree of fluidity for the pouring. Thus the superheating in the smelting or melting furnace must be so great that the melt, after all the losses of temperature incidental to the method, passes into the casting mould or chill with a superheat of about 100°C. or more.

The purpose of the casting mould or the chill is to impart to the melt a definite shape, and to cool it appropriately down to solidification. The casting moulds and chills have in each case a definite cooling power, corresponding to their material and wall thickness. Water-cooled copper chill-moulds have the greatest cooling power. They are followed by graphite chill-moulds and hæmatite chill-moulds for example, and finally by casting moulds of moulding sand.

The solidification of melts in casting moulds or chills begins at the wall of the casting mould or chill, and follows the law $d = k\sqrt{t}$, where d is the thickness of the already solidified layer, t the time that has elapsed up to this point, and k a solidification constant. The constant k is dependent upon the cooling power of the chill-mould, the heat of fusion and the superheat of the melt, and the speed of pouring, which is equivalent to a supplementary delivery of heat into the casting mould or chill.

This invention relates to a method of pouring super-heated molten metals or alloys from a pouring vessel into a casting mould, more particularly into a chill-mould for continuous casting, and to apparatus for casting such super-heated metal melts by the said method.

According to the invention the superheat is withdrawn from the metal melt by cooling the melt on its way from the pouring vessel to the casting mould or chill-mould, before it has reached any melt surface located in or above the mould and corresponding in cross-section to the mould.

Apparatus for casting superheated metal melts according to the invention, includes a casting mould, more particularly a chill-mould for continuous casting and comprises a sheath or casing, consisting of a material of ample thermal conductivity which is stable to the melt, for the guidance of the melt from the pouring vessel to the mould, this sheath or casing being provided with a cooling jacket, which surrounds the pouring jet, and extends right to the surface of the bath in the casting mould or chill-mould.

The invention is illustrated by way of example in the accompanying drawings, in which:

Figure 1 is a diagram illustrating the cooling process; and

Figures 2 and 3 are diagrammatic views of the apparatus employed.

In Figure 1 is represented the dependence of the thermal content I of any given material upon its temperature T. During the cooling of a particle of a melt the thermal content is lowered by removal of heat according to the curve element fl. The external characteristic is a lowering of temperature, but only down to the melting point S. Upon further removal of heat the thermal content, that is to say, the state of energy, is lowered without changing the temperature. The heat of fusion is

now discharged according to the curve element Q_s, and the state of aggregation changes from liquid to solid. Thereupon a lowering of the thermal content is again expressed in a further lowering of temperature corresponding to the curve element f_e. Since the rate of removal of heat depends upon the thermal conductivity of the material that is being poured, the thickness of the cast work-piece or ingot, and the temperature difference, and, at a given cooling power of the casting mould or chill, is to be regarded as constant, to a first approximation, the above-mentioned law of solidification is obtained. The melt solidifies, mostly with the formation of crystals, and the solidified layer grows in a direction opposite to the direction of thermal conduction, until the casting is completely solid.

Whether the solidification occurs exactly at the melting point is dependent upon whether sufficient crystallisation seeds or nuclei are present. If not, then an activating energy or nucleus-forming energy is necessary for their formation, that is to say, the melt must be cooled down to a temperature below its actual solidification temperature. With melts composed of a plurality of components, alloys for example, there is, from the melting point, a range of melting or solidification, with a liquidus line and a solidus line, in dependence upon the composition.

Practical experience in the filling of casting moulds or chills with a melt has shown that the speed with which the filling is effected is dependent upon the assumed cooling power of the casting mould or chill, upon the volumetric capacity to be filled, and upon the superheat of the melt. With a presumed cooling power of the casting mould or chill and a presumed volumetric capacity there remains, as the main influence upon the speed of pouring, the superheat of the melt.

The upper limit, as regards speed of pouring and temperature, is recognised upon the occurrence of longitudinal cracks in the solidified work-piece or billet. They occur owing to the fact that the solidification, with a given cooling power of the casting mould or chill in relation to the thermal content of the melt and the heat subsequently delivered (speed of pouring), is effected too slowly. The relatively thin solidified layer that occurs shrinks, and in so doing lifts away from the casting mould or chill, and can no longer withstand the liquid pressure acting upon it, and therefore fractures. As a counter-measure, the speed of pouring is diminished, or, if possible, the fusion temperature is lowered, or both.

The lower limit with respect to pouring speed and temperature is recognised by the occurrence of "scabs" on the solidified work-piece or billet. They occur owing to the fact that the solidification, with a given cooling power of the casting mould or chill, is effected too rapidly in proportion to the thermal content of the melt and the supplementary supply of heat (speed of pouring). In this case the solidification is effected in the marginal zone of the cast work-pieces or billets so rapidly that the after-flowing melt can no longer combine with the already solidified portion. There remain regular severings of material. As a counter-measure, the speed of pouring, or, if possible, the melting point, is raised, or both.

The invention is based upon these discoveries, its problem consisting in increasing the speeds of pouring that are usual with the various pouring methods, that is to say, increasing the casting outputs, and thus improving the economy of these methods. Frequently, however, it is also desirable, on grounds of quality, to obtain a more rapid solidification of the melt in the casting mould or chill.

According to the invention the maximum casting output in every respect is gained by cooling the melt, before or during its entry into the casting mould, to such an extent that it is still just liquid. Hence, according to the above discoveries, the entire superheat of the melt is withdrawn on its way to the casting mould or chill, so that it reaches the mould with about its liquidus temperature, or even with a super-cooling.

With continuous casting plant it has already been proposed to maintain the casting metal, almost up to its entry into the casting mould, at a constant temperature only just above the melting point, in order to keep the shrinkage of the metal solidifying in the casting mould to a minimum, and to obviate blowholes. In this, however, an increase in the speed of pouring was not contemplated. In this case, moreover, the cast metal was not cooled down to the temperature in question on its way between the pouring vessel and the casting mould, but was already brought, in a completely uneconomical manner, in the pouring vessel itself, to the temperature in question, with the aid of metal melts for example, and was maintained at this temperature by means of heating elements in the region of the admission to the casting mould. The devices required with these previously known methods are unsuitable for rough casting operation, and furthermore do not allow of any increase in the speed of pouring.

As already pointed out, the cooling for the removal of the superheat of the metal melt is effected according to the invention on its way from the pouring vessel to the mould, in such a way that it is at the predetermined temperature in the neighbourhood of the surface of the bath in the casting mould or chill. By this means the degree of liquidity of the melt, which participates in determining the speed of flow is reliably maintained as long as possible. The cooling is advantageously applied to a pouring jet the cross-sectional area of which, as known in itself, is only a fraction of that of the casting mould or chill. The

removal of the excess heat at the pouring jet is particularly intensive, owing to the smallness of the cross-section of the latter, and is accordingly also readily adjustable. In this case it is an advantage if the pouring jet is given as large a surface area as possible.

In a further development of the invention the temperature of the pouring jet is measured at the end of the cooling operation, and, in accordance with the temperature measurement, the speed of pouring and/or the cooling power is correspondingly controlled. The speed of pouring is in this case regulated, in a manner known in itself, by means of gaseous pressure upon the surface of the melt to be poured. To obviate oxidation of the melt in the cooling region, the cooling operation is effected preferably with the exclusion of air.

Apparatus for carrying out the method of the invention is formed in an appropriate manner by a sheath or casing guiding the pouring jet, and consisting of a material resistant to the melt, of adequate thermal conductivity, and provided with a cooling jacket, the guiding sheath extending right to the surface level of the bath in the mould. In the region of the surface of the bath the pouring jet sheath is extended radially outwards in such a way that it comes close to the internal wall surface of the mould. Any irregular solidification of the melt in the mould is thereby effectually prevented.

In order that the surface of the bath may also be protected against the oxygen of the atmosphere, the radial extension of the sheath is in approximately airtight contact with the chill-mould wall; or else, between the outer region of this part of the sheath and the chill-mould wall, an atmosphere of protective gas is applied. For the measurment of the temperature in the neighbourhood of the surface of the bath, a thermo-couple is arranged in an appropriate manner in the sheath.

Constructional examples of apparatus according to the invention for carrying out the method are diagrammatically illustrated in Figures 2 and 3.

In these Figures, 1 denotes a sheath or casing acting as a cooling means. This cooling sheath is radially extended at its lower end 3, to correspond to the cross-scetional form of the chill-mould 2. The sheath 1 may advantageously consist of graphite or silicon carbide, or of some other material that is stable to the melt, and which also has the ample thermal conductivity requisite for the cooling. The free cross-section 4 of the sheath 1 for the guidance of the melt (represented by the arrow 5) coming from a pouring container, not shown, to the chill-mould 2, may advantageously be made of elongated form rectangular or elliptical), so as to obtain as large a surface area as possible for the effective discharge of heat. According to Figure 2 the sheath 1 is surrounded by a cooling jacket 6, and according to Figure 3, with a cooling coil 7, for the removal of heat. As indicated by arrows 8 the cooling medium flows into the cooling jacket 6 or into the cooling coil 7 below, and according to the arrow 9 it flows out at the top. The cooling device therefore works in a known manner on the counter-current principle. The quantity and speed of flow of the cooling medium are controlled according to the cooling power required. The speed of pouring, that is to say, the speed with which the melt flows through the sheath 1, that acts as a cooling device, is regulated by known means according to the cooling power and the requisite speed of filling of the casting mould or chill 2, for instance by means of a pressure applied above the melt in the pouring vessel.

The dimensioning of the sheath 1 must be adjusted to the required casting capacity, the passage through the sheath 1 possibly being subdivided into a plurality of passage apertures for the melt.

A short distance above the outlet aperture 10 of the sheath 1 a thermo-couple 11 is provided, with the help of which the temperature of the melt is continuously measured. The entire pouring operation may be controlled according to this measurement.

By the lid-like closure 3 provided by the sheath 1, any thermal radiation from the bath surface G is considerably reduced.

WHAT WE CLAIM IS:—

1. A method of pouring superheated metal melts from a pouring vessel into a casting mould, particularly in to a chill mould, for continuous casting characterised by the feature that the superheat is withdraw from the metal melt by cooling on the way to the casting mould or the chill, before it has reached any melt surface located in or above the mould and correspondingly in cosss-section to the mould.

2. A method of pouring melts as claimed in Claim 1, wherein the cooling of the metal melt is regulated in such a way that it is still just liquid when it comes into the neighbourhood of the surface of the bath in the casting mould or the chill.

3. A method of pouring melts as claimed in Claim 1 or 2, wherein the cooling is applied to a pouring jet the cross-sectional area of which is only a fraction of that of the casting mould or chill.

4. A method of pouring melts as claimed in Claim 3, wherein the temperature of the pouring jet is measured at the end of the cooling operation, and the pouring speed and/or cooling power is controlled in accordance with this measurment of temperature.

5. A method of pouring melts as claimed in any one of claims 1 to 4, wherein the speed of pouring is regulated by means of gas pressure acting upon the melt to be poured.

6. A method of pouring melts as claimed in Claim 3, wherein the pouring jet is of rec-

tangular or elliptical cross-section, so as to provide as large a surface area as possible.

7. A method of pouring melts as claimed in any one of the claims 1 to 6, wherein the cooling operation is effected with the exclusion of air.

8. Apparatus for casting superheated metal melts, including a casting mould, more particularly a chill-mould for continuous casting, by the method claimed in any one of the preceding claims, comprising a sheath or casing consisting of a material of ample thermal conductivity which is stable to the melt, for the guidance of the melt from the pouring vessel to the mould, this sheath or casing being provided with a cooling jacket for the pouring jet, which extends right down to the level that will normally be reached by the surface of the bath in the casting mould or chill.

9. Apparatus for casting melts as claimed in Claim 8, wherein the sheath, in the neighbourhood of the surface of the bath, is radially extended outwards in such a way that it screens the free cross-section of the casting mould or chill from the exterior.

10. Apparatus for casting melts as claimed in Claim 9, wherein the radially extended portion of the sheath makes approximately airtight contact with the wall of the chill.

11. Apparatus for casting melts as claimed in Claim 9, characterised by the feature that between the outer region of the radially extended portion of the sheath and the wall of the chill an atmosphere of protective gas is provided.

12. Apparatus for casting as claimed in any one of the claims 8 to 11, wherein a thermocouple is provided in the sheath in the neighbourhood of the surface of the bath.

13. A method of pouring superheated metal melts from a pouring vessel into a casting mould, particularly into a chill-mould, for continuous casting substantially as hereinbefore described.

14. Apparatus for casting superheated metal melts from a pouring vessel into a casting mould, more particularly a chill-mould for continuous casting substantially as hereinbefore described with reference to the accompanying drawings.

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Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1968.
Published by the Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

1131624 COMPLETE SPECIFICATION

1 SHEET This drawing is a reproduction of the Original on a reduced scale

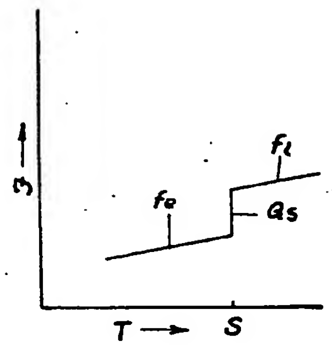

FIG. 1

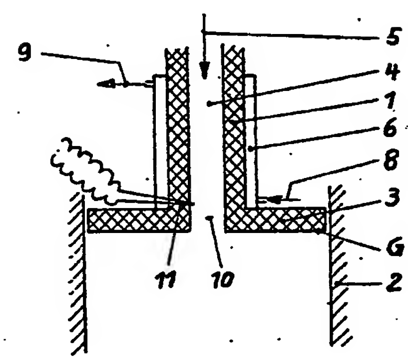

FIG. 2

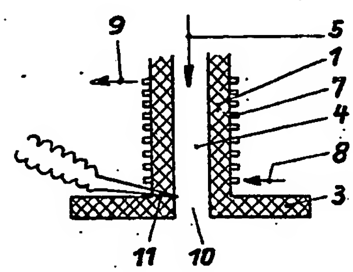

FIG. 3